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Gonad development in the freshwater oyster *Etheria elliptica* (Bivalvia: Etheriidae) in northern Ghana

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Gonad development in the freshwater oyster *Etheria elliptica* from the White Volta River at Nawuni and the Oti River at Sabari (northern Ghana) was studied by histological examination from March to July 1999. Five developmental stages — developing, ripening, ripened, spawning and spent — were encountered in both populations. The dominant stages were ripening and spawning, whereas spent gonads were rare. Males and females were nearly equally represented in the White Volta River stock, but the Oti River stock had more females than males. Hermaphrodites were encountered occasionally in both populations. By the end of the dry season (March–April), gonad development in both populations had progressed to the ripening stage, suggesting that they began active differentiation much earlier. From May through June, when the rains began and intensified, spawning had begun and was progressing. It was not possible to establish the limits of the breeding season because sampling was limited to only part of the year.

Keywords: hermaphrodite, sex ratio, spawning, traditional fishery, Volta Lake tributaries

Introduction

The freshwater oyster *Etheria* (Unionoida: Etheriidae) has inner gills with a marsupial, and its relatively small eggs are only about 0.05 mm in diameter (Mandahl-Barth 1988). Beyond the egg stage, nothing else is known about the early ontogenic development of *Etheria* (Bogan and Roe 2008). The scant literature available on the family is limited to the geographical distribution, shell cementation and taxonomy of the group based on shell characteristics and habitats (Pilsbry and Bequaert 1927, Yonge 1962, van Damme 1984, Mandahl-Barth 1988). Detailed knowledge of its reproductive biology is required to understand the life history of *Etheria* and its potential as a fishery resource. In Ghana, the freshwater oyster *Etheria elliptica* occurs in the rivers of the Volta River system in the north of the country. The oyster fishery in the area is an indigenous industry of great antiquity (Pilsbry and Bequaert 1927), currently practised mainly by women who collect and process the oysters for food and income as a major source of livelihood.

Since no literature exists on the reproductive biology of the organism it is important to study its reproductive biology, seasonal gonadal changes and spawning regime, especially in relation to the collection of the young or spat (Durve 1965, Quayle 1988). In this study the seasonal changes in developmental stages of the gonads of *Etheria elliptica* in two major tributaries of the northern section of Volta Lake, Ghana, were monitored.

Materials and methods

Study area and sampling sites

The study was undertaken in the northern region of Ghana (Figure 1) at Nawuni on the White Volta River and Sabari on the Oti River. The sampling sites were chosen based on ease of access and the availability of oysters. Both sites are popular oyster fishing grounds, as evidenced by the presence of heaps of shells along the banks of the rivers.

Gonad examination and sex ratio analysis

The size (height) of oysters from both sites used for histological study ranged from 42 to 136 mm. Height was measured to the nearest 1.0 mm from the tip of the umbonal end of the upper valve to the ventral margin (Quayle and Newkirk 1989). Gonad development was studied by monthly histological examination from March to July 1999. Parts of the visceral mass and mantle were fixed in Bouin's solution for 24 hours, washed and preserved in 70% alcohol and later dehydrated in an automatic tissue processor (Shannon Elliot SE 400), through a serial dilution of alcohol (i.e. 80%, 90% and 100%), chloroform and molten paraffin wax, for 18 hours in the laboratory. The tissues were then embedded in paraffin wax. Using a microtome (Model, Bright 5040), 7–10 µm sections were cut and stained with Ehrlich's haematoxylin and counter-stained with eosin (Gridly 1960, Baker et al. 1962).

Prepared sections were examined microscopically to identify sex. The gonads were assigned arbitrary stages (I–V) according to their stage of development (Durve 1965, Yankson 1982, Blay 1986, Yankson 1996). The proportion of individuals in each developmental stage was computed to assess the progression of gonad development. The sex ratio of the sample populations was determined from the histological analysis.

Results

Sex ratio

Histological examination revealed that the gonads formed part of the visceral mass, lying between the digestive glands and the body wall. In the Oti River the sex ratio was skewed towards females in April and June (mean M:F = 1:2.3), but was nearly equal in other months (mean M:F = 1:1.1). In the

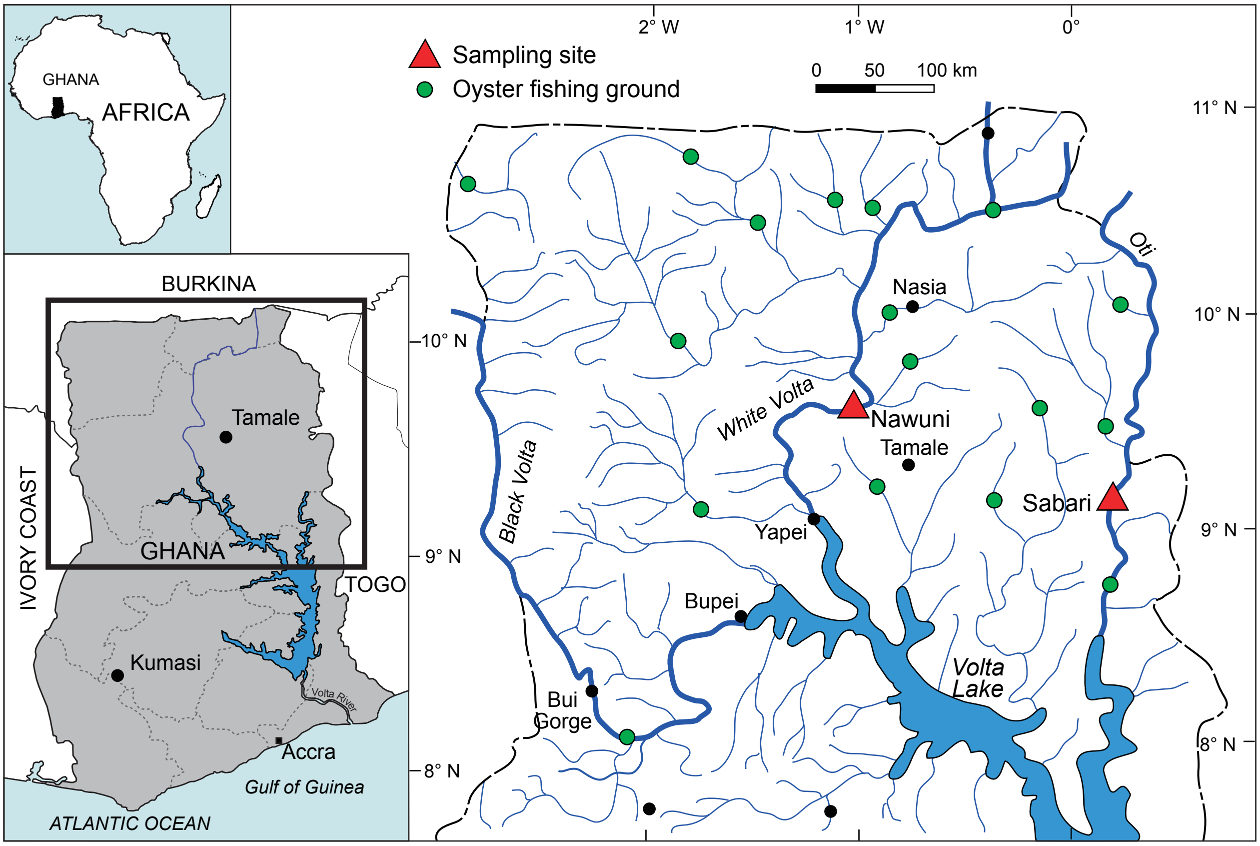

Figure 1: Map of northern Ghana showing locations of major traditional oyster fishing grounds and the sampling sites

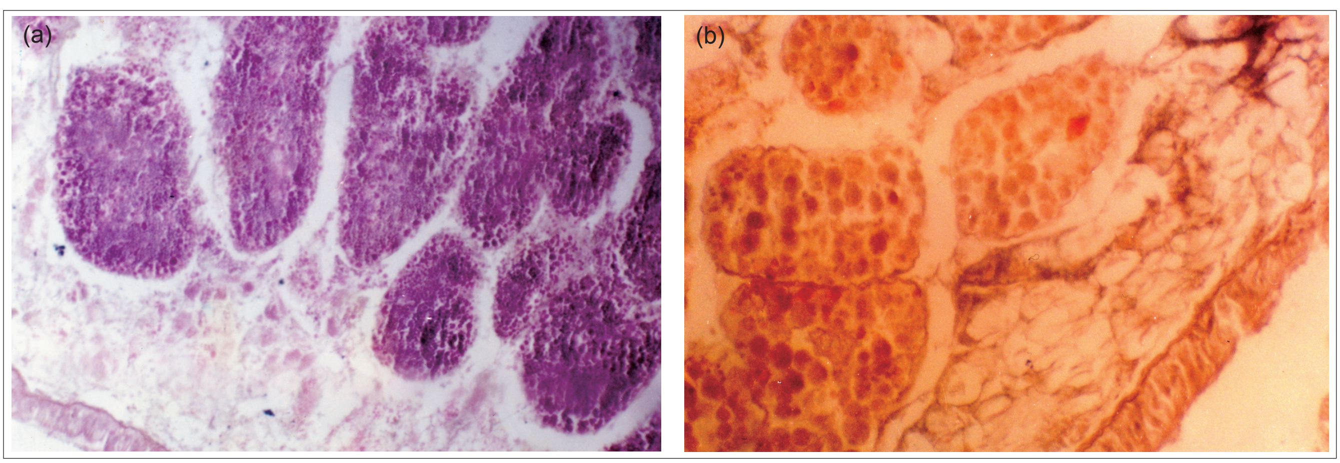

Figure 2: *Etheria elliptica* gonads in Stage I (developing), ×200: (a) testis, (b) ovary

White Volta River, however, the sex ratio was nearly equal (mean M:F = 1.2:1). Overall, only 5.5% of the animals were hermaphrodites.

Gonad development

Stage I, developing gonad (Figure 2a, b): Testes and ovaries at this stage showed developing spermatogonia and oogonia, respectively. In some specimens primary and secondary oocytes and spermatogonia partially or completely filled the lumina of the follicles, and the connective tissue present had begun to disappear.

Stage II, ripening gonads (Figure 3a, b): The amount of connective tissue in both male and female gonads had reduced considerably. In the ovaries many maturing ova were present, closely attached to each other, and were separated from the follicular wall. In the testes the follicles were completely filled with sperm at all stages of spermatogenesis (spermtogonia, spermatocytes, spermatids and spermatozoa). The spermatozoa were relatively few and were confined to the centre of the follicles, while earlier stages occupied the follicular walls.

Stage III, ripe gonads (Figure 4a, b): Connective tissue in both ovaries and testes had completely disappeared. Mature, detached (ovulated) ova filled the lumina of enlarged follicles. In the testes, follicles were fully packed with spermatozoa.

Stage IV, spawning gonads (Figure 5a, b): Female follicles contained fewer ovulated eggs than in the previous stage, indicating that some spawning had already occurred. Similarly, in the male follicular cells spermatozoa were fewer than in the previous stage, indicating that some sperm-shedding had occurred.

Stage V, spent gonads (Figure 6a, b): The gonads had shrunk as a result of spawning. Both ovaries and testes showed empty follicles, indicating that spawning activity had been completed.

Hermaphrodites

Individuals with both ovarian and testicular tissue in the same gonad (hermaphrodites) occurred in samples from both rivers. The ovarian and testicular tissue occurred in different proportions, lying between the digestive glands

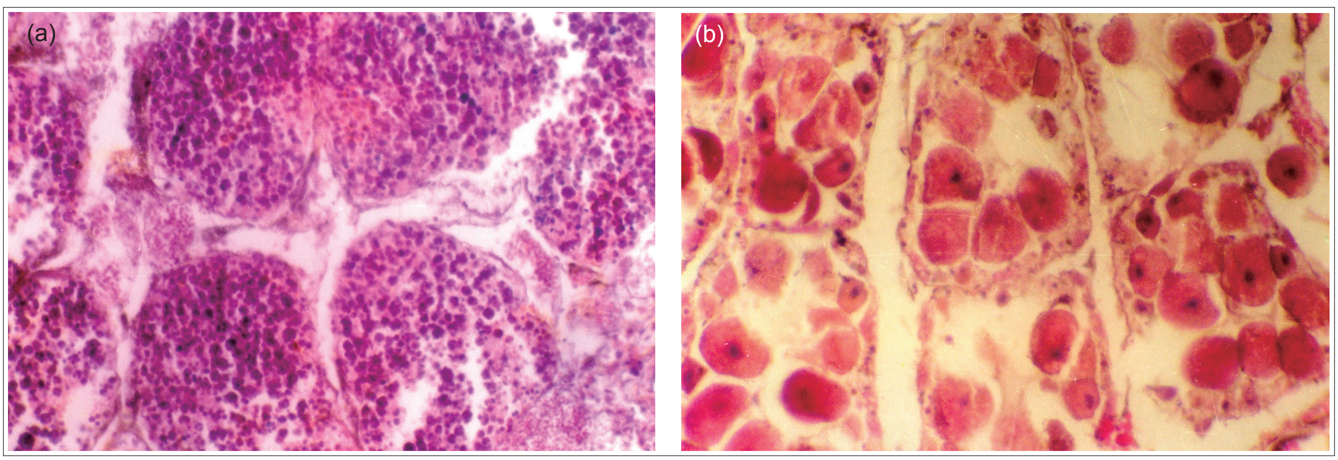

Figure 3: *Etheria elliptica* gonads in Stage II (ripening), ×200: (a) testis, (b) ovary

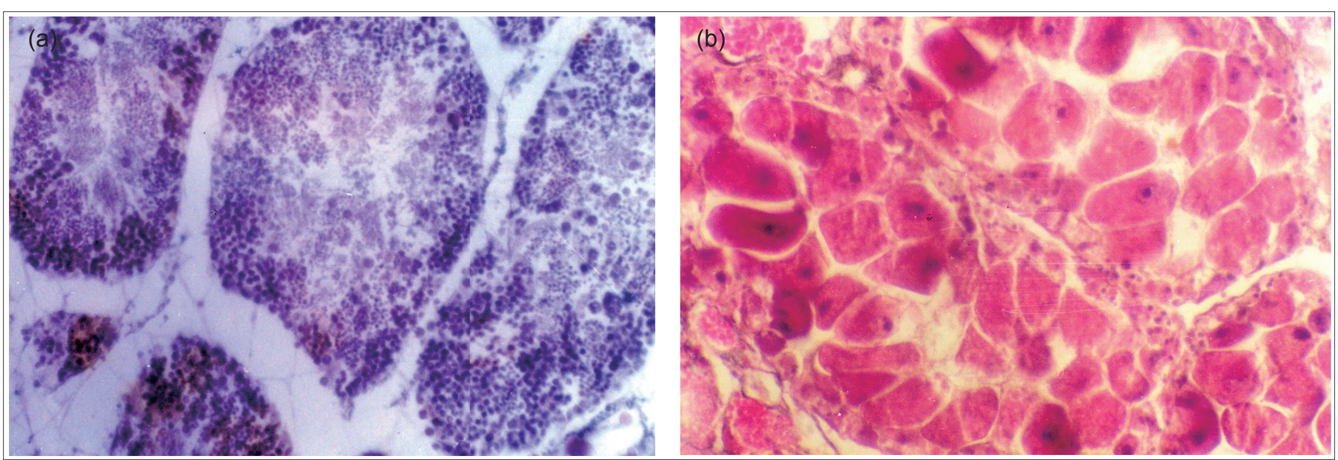

Figure 4: *Etheria elliptica* gonads in Stage III (ripe), ×200: (a) mature testis, (b) mature ovary

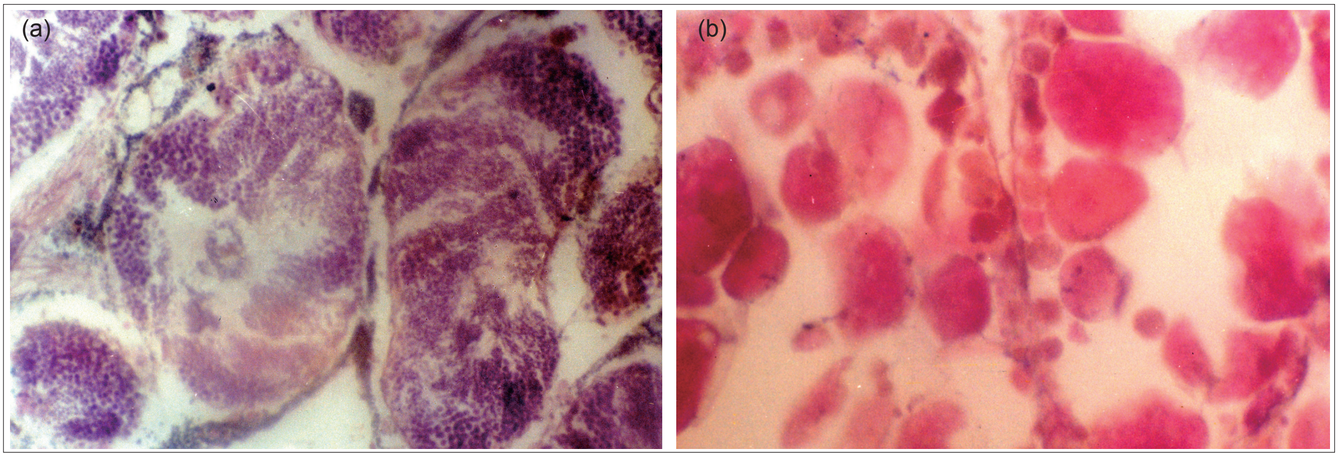

Figure 5: *Etheria elliptica* gonads in Stage IV (spawning), ×200: (a) testis with few spermatozoa, (b) ovary showing few ovulated eggs

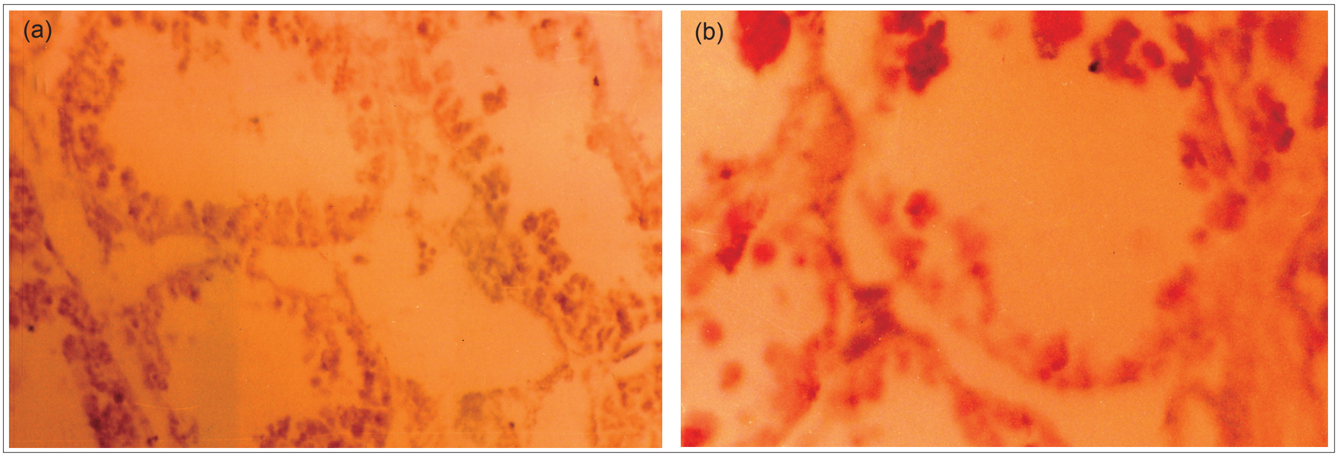

Figure 6: *Etheria elliptica* gonads in Stage V (spent), ×200: (a) testis devoid of spermatozoa, (b) ovary with very few ova

and the body wall. Both ovarian and testicular follicles contained various stages of oogenesis and spermatogenesis (Figure 7), suggesting that the hermaphrodites were functional.

Monthly changes in gonad stages

Figure 8a–e represents the monthly frequency distribution of gonad activity of the two populations. By March, gonad development had already begun in both populations. Spawning activity began in April and progressed steadily, climaxing in July. Spent male and female gonads were rare in both populations, and occurred only towards the end of July, suggesting the cessation of spawning activity in certain individuals.

Discussion

In that the gonads of *Etheria elliptica* formed part of the visceral mass, occurring between the digestive glands and the body wall, they show some resemblance to marine oysters. Some individuals were hermaphrodites, and it is generally recognised that some gonochoristic unionoid bivalves exhibit hermaphroditism (Boss 1982, cited in Walker et al. 2006). Critical observation of the hermaphrodite gonads showed that both the ovarian and testicular cells were active and therefore could not represent transitional stages of sex reversal, as would be expected if one sex was active and the other was not. The overall sex ratio in both populations was similar and did not deviate significantly from the expected 1:1 ratio. The Oti River stock, however, had more females in some months. This agrees with the observations of Blay (1986) on *Aspatharia sinuata* (Iridinidae) and Obodai (1990) on *Crassostrea tulipa* (Ostreaidae), both of which are essentially gonochoristic (dioecious) species with insignificant incidence of hermaphroditism (Yokley 1972). It was difficult to explain the sex ratio deviation in the Oti stock. Sex reversal was discounted, because of the low frequency (5.5%) of hermaphrodites and the lack of evidence of transitional stages of sex reversal. However, in the West African

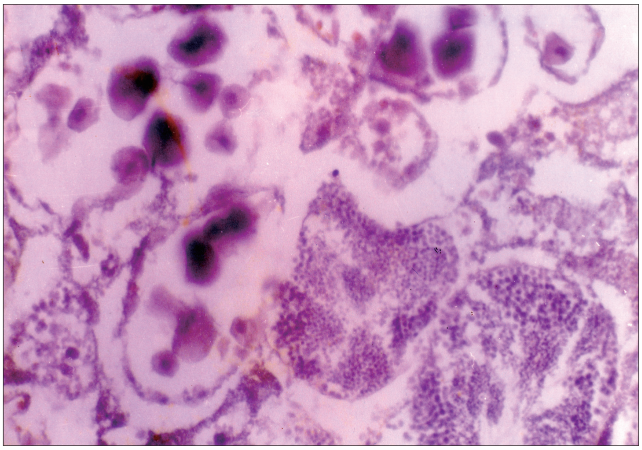

Figure 7: Hermaphrodite gonad of *Etheria elliptica* showing both testicular and ovarian follicles side by side, ×200

bloody cockle, *Anadara sinilis*, protandic hermaphroditism has been observed (Yoloye 1974), which suggests sex reversal from male to female, although Yankson (1982) felt that the species is basically gonochoristic.

By the end of the dry season (March–April), gonad development in both populations had progressed to the ripening stage already, indicating that the gonads began active differentiation much earlier. From May through June, when the rains began and intensified, most individuals possessed fully ripened gonads and spawning had begun. The response to environmental cues for the commencement of gonad development, maturation and spawning was similar in both populations. In both *Aspatharia sinuata* (Iridinidae) (Blay 1986) and *Pleurobema cordatum* (Unionidae) (Yokley 1972) spawning is intensified in the rainy season. The response of reproductive activity to seasonal changes appears to be to ensure the best environmental conditions and the provision of abundant food for the growth and maturation of the gonads, and for the survival of the young. It is for this reason that reproduction in riverine aquatic animals is generally associated with the hydrological cycle, including rainfall and flow regimes (Welcomme 1985).

In the present study it was not possible to establish the exact times when reproductive activity began and ended, because sampling was limited to only a part of the year (March–July) due to logistical problems. An entire year is needed to investigate and describe the complete life history of the oyster, and to establish the limits of its breeding season, which would be useful for regulating the traditional oyster fisheries in the White Volta and Oti rivers for sustainable exploitation. In addition, since the life cycle of Etheriids is still unknown (Van Damme 1984), the suggested extended study would provide the needed baseline information for more detailed investigations into their reproductive biology.

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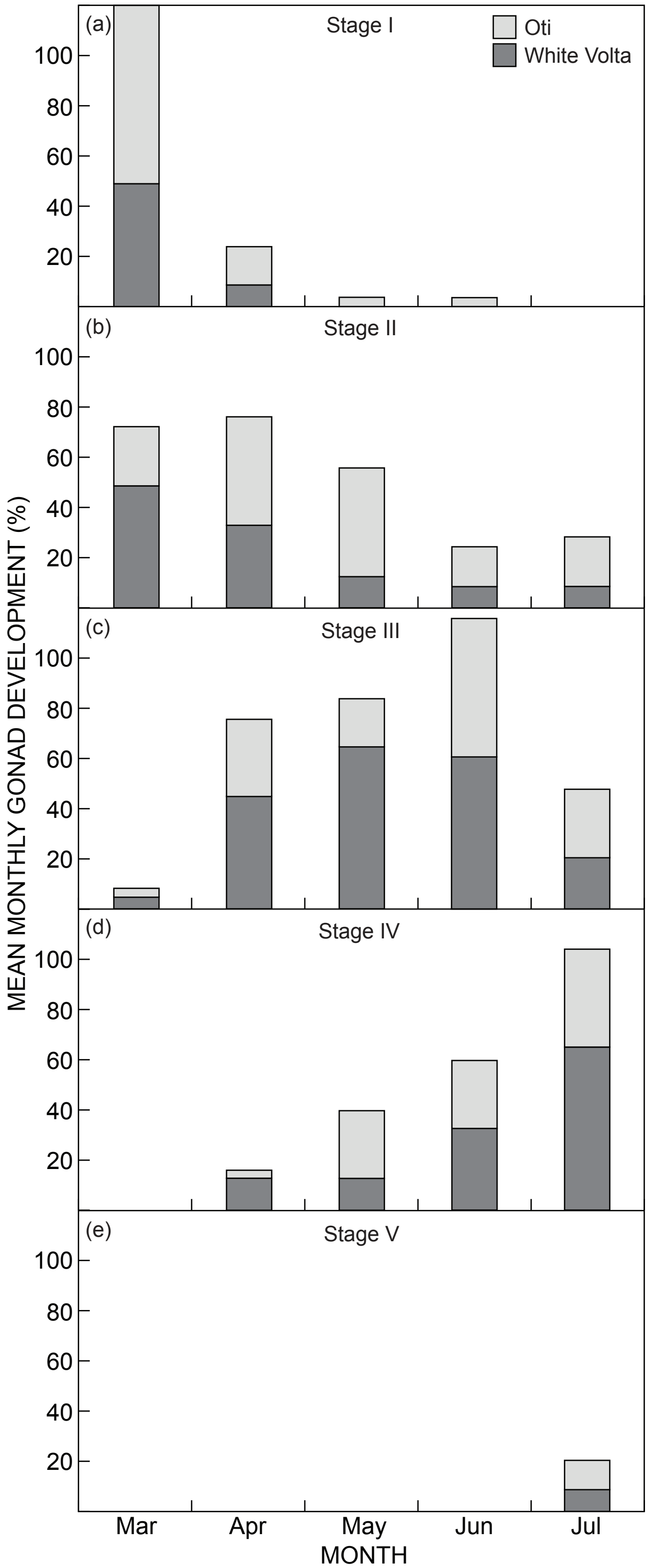

Figure 8: Mean monthly percent gonad development Stages I–V (males and females combined) in the Oti River and White Volta River populations of *Etheria elliptica*: (a) developing, (b) ripening, (c) ripened, (d) spawning and (e) spent

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